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REPORT NO. 1,035

PROCEDURAL EFFECTS IN THE MEASUREMENT OF STATIC MUSCLE STRENGTH

(Progress Report)

by

Lee S. Caldwell, Ph.D.

and

K. H. E. Kroemer, Dr. Ing.

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3538

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UNITED STATES ARMY
MEDICAL RESEARCH AND DEVELOPMENT COMMAND

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6570TH AEROSPACE MEDICAL RESEARCH LABORATORY
Wright-Patterson AFB, Ohio 45433

30 April 1973

Military Performance:
Physical Decrement and Enhancement
Work Unit No. 128
Psychiatry
Task No. 03
Research in Biomedical Sciences
DA Project No. 3A061102B71R

USAMRL REPORT NO. 1,035
DA PROJECT NO. 3A061102B71R

ABSTRACT

PROCEDURAL EFFECTS IN THE MEASUREMENT OF STATIC MUSCLE STRENGTH

OBJECTIVE

To compare measures of isometric (static) muscle strength obtained with three commonly used sets of instructions.

METHOD

Maximum voluntary hand-grip strength was measured using three types of instructions for exerting force on the transducer. Both the time required to reach maximum output and the maximum applied force were measured.

SUMMARY

All three instruction conditions yielded reliable measures of strength and time-to-maximum output. The variability of the data, however, differed appreciably among the instruction conditions.

CONCLUSIONS

The results emphasize the necessity for explicit instructions to the subjects in strength assessment studies and the importance of reporting in detail all factors which might influence the measure obtained.

PROCEDURAL EFFECTS IN THE MEASUREMENT OF
STATIC MUSCLE STRENGTH

INTRODUCTION

Early in 1972 a group of individuals interested in the testing of voluntary muscular strength agreed that the existing disparity and confusion in strength testing warranted standardization of at least one procedure. The consensus was that the effort to standardize should be initially limited to the assessment of static (isometric) strength. This was chosen from many possible "strengths" (such as explosive, dynamic, isotonic, lifting, etc.) because it has traditionally been measured and frequently reported. Anyone who has consulted the various handbooks and human engineering guides to find the weight lifting capabilities of man, the maximum strength of hand-grip, the difference in strength of men and women, etc. is aware of the considerable diversity in the reported data. Even close examination of the "classic" studies may not relieve the confusion since even in most of these it is difficult to determine the characteristics of the subject sample, the instructions given the subjects, the method of measurement, the reliability of the measures, etc. Kroemer and Howard* examined 50 reports drawn randomly from their file of studies on human strength published within the past 35 years and found that in only 10% of the sample were both the method of force application and the statistical index used clearly stated. Obviously, it is time to come to some agreement about terminology and definitions, methods of assessment, statistical indices, etc. so that results from various sources can be compared or combined to yield a more accurate picture of man's physical capabilities and limitations than is possible at present.

One of the most important factors which influences performance is the subject's instructional set: or his understanding of the task requirements. Apparently, in such a "simple" situation as measuring strength, many researchers either do not consider instructions important, or they simply fail to report them. Kroemer and Howard* used different instructions and found that the method of force generation and application influenced the measure of strength obtained. In one condition in which the subjects pushed with both hands against a stationary wall, sudden force application yielded a mean score 13 kp** higher than when force was applied gradually, and 24 kp higher than when force was exerted gradually and held for 5 sec. In another condition ("laterally braced"), which involved a smaller muscle mass but better body stabilization, the three instruction conditions yielded different strength scores though not in the same order as for the first ("forward leaning") condition. The difference in results for the instruction conditions emphasizes the importance for explicit instructions to the subjects and of reporting these with the data.

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*Kroemer, K. H. E. and J. M. Howard. Towards standardization of muscle strength testing. Med. and Sci. in Sports, 2: 224-230, 1970.

**Kilopond (kp) = kilogram-force (kg_f) or 2.2 lb.

The difference between the results obtained by the two techniques of generating force suggests that the advantage of the "jerk" method over the others may be due to the difference in the masses of muscle involved in the two responses since rapid force application was relatively more advantageous in the "forward leaning" than in the "laterally braced" condition.

The purpose of the present study was to measure the strength of handgrip utilizing three instruction conditions, and to compare the results with those reported by Kroemer and Howard (1970).

METHOD

Subjects. The subjects were 34 Army enlisted personnel who had just finished basic training. They were volunteers unselected for size, strength, or experience. All had been given physical examinations and were certified as fit for strenuous work. The only other requirement was that they be willing to participate voluntarily in various kinds of psychological research. The group had an average age of 20.0 years with a standard deviation (SD) of 1.6 years. Mean stature was 177.8 cm with an SD of 5.7 cm, and mean weight was 70.3 kg with an SD of 7.2 kg.

Apparatus. The basic apparatus consisted of an isometric handle, a strain amplifier, and an ink-writing recorder. The handle consisted of two parts. The outer portion of the handle was a square with three sides composed of heavy aluminum and the fourth was a leaf of tool steel. The inner portion of the handle was a smaller square also constructed of aluminum which was attached to the outer shell by a threaded bolt. The bolt fit through a hole in the center of the leaf spring. Strain gages were cemented on the inner and outer surfaces of the spring on either side of the bolt. The surfaces contacted by the hand and fingers were rounded and covered by a thin layer of surgical tape. Thus, when the subject squeezed on the handle the spring was slightly flexed and the gages changed length and resistance. The gages, which formed the input circuit of the strain amplifier, were balanced by controls on the amplifier so that under normal conditions no current flowed through the bridge. Any applied pressure, however, resulted in a state of resistive imbalance in the bridge and a current flow directly proportional to the applied force was detected. amplified, and fed into the recorder. The handle was calibrated using known weights applied to the surface of the handle on which the fingers applied pressure. The subject sat in a comfortably padded straight chair with both arms hanging loosely at his sides. He was cautioned not to grasp his body or the chair with his free hand.

Procedure. The handle was adjusted so that a tape stretched around the heel and finger portions of the handle read 15.5 cm. This setting was used for all subjects. The subjects were given two duplicate practice trials each practice session with one of the three instruction conditions. The pair of practice trials was separated by a rest period of 2 min, and the sessions were at least 24 hr apart. The order of the instruction

conditions was counterbalanced, except that there was one extra subject. In the experimental sessions the instruction and pacing of trials were identical to those used in practice. The verbatim instructions for the three conditions were as follows: (a) "Jerk" - "Today I want you to suddenly jerk the handle as hard as you possibly can. When you've reached your maximum, release the handle on your own." (b) "Increase" - "Today I want you to gradually squeeze the handle and when you've reached your maximum, release the handle on your own." (c) "Hold" - "Today I want you to squeeze the handle as hard as you can for 5 sec while I count. Try to reach your maximum at about the count of 'two' and hold it until I reach the count of '7'."

Just before each trial began the experimenter said, "Are you ready?---Go."

RESULTS

The data were analyzed to determine: (1) the effects of instructions on the time required to reach maximum force application; (2) the relationship between instruction conditions and the obtained strength measures; and (3) the relationship between strength and method of force generation. (The results are based on the mean of the two trials because t-tests revealed no significant differences in either the time or strength measures for the two trials.)

1. Time to reach maximum force application.

a. "Jerk" - With instructions to apply force as rapidly as possible, 38% of the subjects reached their maximum output within the first second, 41% took between 1 and 2 sec, 12% required from 2 to 3 sec, and 9% took more than 3 sec. The distribution of the times required to reach maximum strength is shown in Figure 1.

b. "Increase" - The instruction to increase gradually to maximum output and then release led to extremely variable performance, as follows: 12% attained maximum force within 1 sec; 15% took from 1 to 2 sec; 21% reached maximum between 2 and 3 sec; another 21% took from 3 to 4 sec; 6% needed from 4 to 5 sec; and 27% took more than 5 sec.

c. "Hold" - Only 3% of the subjects reached maximum output in the first second, 24% required 1 to 2 sec, 29% took 2 to 3 sec, 26% took 3 to 4 sec, 9% required 4 to 5 sec, and the remaining 9% reached maximum output after 5 sec.

For all instruction conditions the times-to-maximum data were skewed toward the longer times. The g_1s* (a measure of skewness) for "Jerk,"

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*

$$\frac{\Sigma X^3}{\frac{\Sigma X^2}{N} \sqrt{\frac{\Sigma X^2}{N}}}$$

"Increase," and "Hold" were 1.54, 1.84, and 1.67, respectively. The slight bi-modality for the "Jerk" condition reflects the tendency of some subjects to re-position the dynamometer in their hands after being told to respond even though they had been given a preparatory signal. This tendency seemed to be most evident when they were told to apply pressure suddenly.

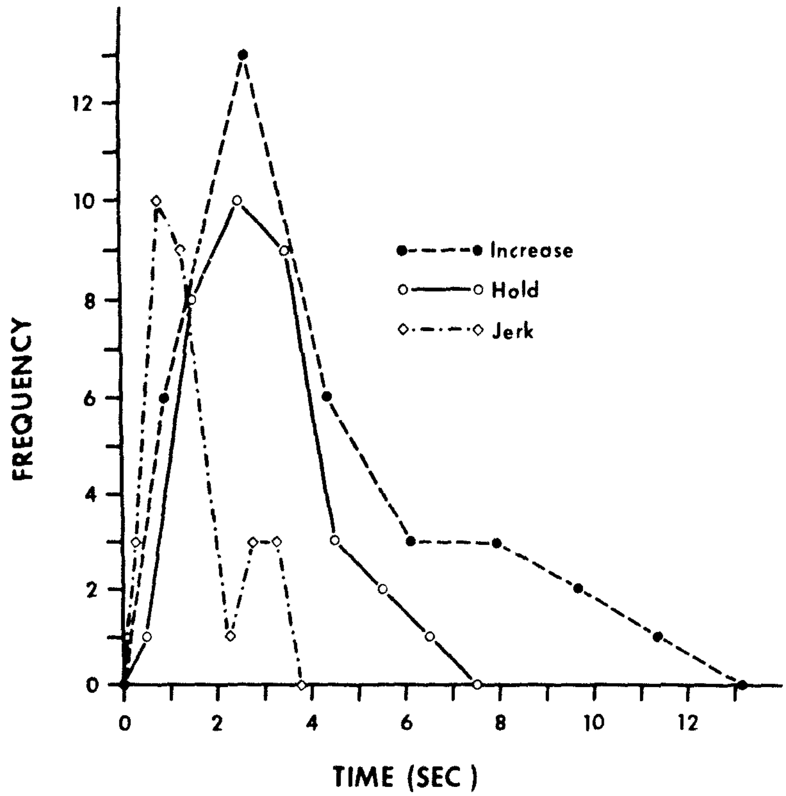

Fig. 1. Number of subjects who required various times to reach maximum voluntary grip strength with three instruction conditions.

In 31 of the 34 cases maximum force was attained fastest with the "Jerk" instruction. In 19 cases the longest times were obtained in the "Increase" condition, and in 14 instances longest times were found with "Hold" instructions. All t-tests of the differences between instruction conditions were significant at the 1% level of confidence. The mean time-to-maximum strength for the "Jerk," "Increase," and "Hold" conditions were 1.4, 4.1, and 2.8 sec, respectively.

2. <u>Effect of instructions on measures of strength</u>.

There was little difference in the measures obtained with the various instructions: mean strength was 55.4 kp for the "Jerk" and

"Increase" conditions and 52.4 kp for "Hold." The standard deviations were very similar, too, and ranged from 7.9 kp for "Increase" to 8.0 kp for "Hold." The "Hold" measures were significantly smaller than the others ($p < .01$), however. For only four subjects was strength greatest under the "Hold" condition. The strength data were also skewed toward the higher values, as shown in Figure 2. The g_1s for "Jerk," "Increase," and "Hold" were 1.35, 1.55, and 1.47, respectively.

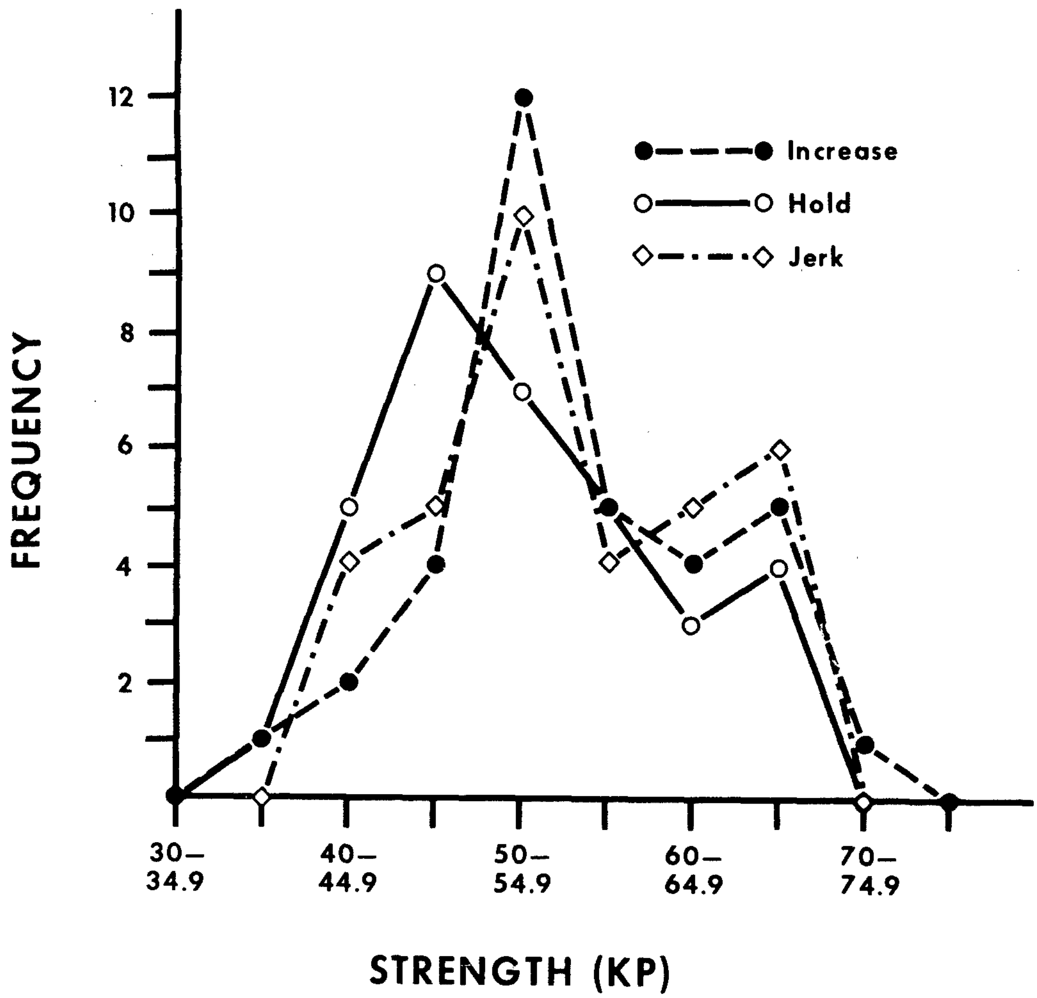

Fig. 2. Distribution of maximum grip strengths by categories for three instruction conditions.

All instruction conditions yielded reliable measures of strength. The test-retest correlations and the intercorrelations of the strength measures are shown in Table 1. The differences in reliability were insufficient to provide a basis for recommending one procedure over the others.

TABLE 1

Intercorrelations of Strength Measures

	Jerk	Increase	Hold
Jerk	.94	.77	.86
Increase	-	.92	.89
Hold	-	-	.95

3. Relationship between strength and rate of force generation.

Since Kroemer and Howard's (1970) data suggests that the rate of force application influences measured strength--at least when large muscle masses are involved--the present results were analyzed to see if the same relationship would hold for the relatively small muscle masses involved in manual squeezing. Product-moment coefficients of correlation between rate and strength for "Jerk," "Increase," and "Hold" were -.23, -.27, and -.05, respectively. None of the *r*s attained significance at the 5% level of confidence.

DISCUSSION

These results provide additional support for Kroemer and Howard's (1970) contention that instructional set exerts an influence on the measure of strength, and that without explicit instructions subjects tend to develop their own strategies reflecting their diverse interpretation of the task. Even though measures obtained with "Increase" instructions were highly reliable, the extreme variability in the time taken to develop maximum force reduces the impressiveness of the correlation: one should remember that heterogeneity inflates the coefficient of correlation. This consideration makes the *r*s for the "Jerk" and "Hold" data somewhat more impressive.

It is apparent that instructions to apply a gripping force suddenly did not generally lead to explosive expenditure of energy. This may reflect the realization by most subjects that sudden application of force generates greater output only when large muscle masses are involved, or that explosive isometric muscle contractions may produce considerable discomfort. Only three of the 34 subjects reached their maximum force in less than 0.5 sec. The shortest time was 0.3 sec, so the resultant measure could hardly be classified as "explosive strength."

CONCLUSIONS

The results of this study emphasize the necessity for explicit instructions to subjects in strength assessment studies, and the importance

of reporting in detail all factors which influence the generation of force and its application to a transducer. Had an effort been made to define strength, and an agreement been reached about reporting all relevant details of assessment studies in years past, our handbooks, texts, etc. would now contain information more directly usable by human factors specialists, plant safety officers, and others.

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* US Army Medical Research Laboratory Fort Knox, Kentucky 40121	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

PROCEDURAL EFFECTS IN THE MEASUREMENT OF STATIC MUSCLE STRENGTH

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Progress Report

5. AUTHOR(S) *(First name, middle initial, last name)*

Lee S. Caldwell, Ph.D. and K. H. E. Kroemer, Dr. Ing.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
30 April 1973	7	1

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 3A061102B71R c. Task No. 03 d. Work Unit No. 128	9a. ORIGINATOR'S REPORT NUMBER(S) 1,035 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	US Army Medical Research and Development Command, Washington, D. C. 20314

13. ABSTRACT

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UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Muscle Strength						
Isometric Contractions						
Standardization						
Methodology						

☆ U.S. GOVERNMENT PRINTING OFFICE: 1973—758-943 /3115 5-II

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